EFFECTS OF HAY AND FIRE MANAGEMENT ON BREEDING BIRD COMMUNITIES AND ARTIFICIAL NEST SUCCESS ALONG THE BUFFALO NATIONAL RIVER, ARKANSAS

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science

By

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CHAPTER 1

EFFECTS OF HAY AND FIRE MANAGEMENT ON BREEDING BIRD COMMUNITIES ALONG THE BUFFALO NATIONAL RIVER, ARKANSAS

This chapter is written in the format of a manuscript for the *Wilson Bulletin*.

ABSTRACT

Research was conducted in 1994 along the Buffalo National River, a national park in the Arkansas Ozarks, USA, to determine the effects of hay and fire management on breeding neotropical migrants. Few studies have evaluated the effect on breeding birds of land uses within boundaries of national rivers. Fixed-radius point-count censuses were performed in hayfields, old fields, burned deciduous forest, and mature secondary deciduous forest. Hayfields had no nesting birds, but old fields and burned forests supported different bird community assemblages than did secondary forest. The highest number (16) of neotropical migrant species was found in old fields, followed by burned forest (12). Habitat variables describing floristic structure were entered into a stepwise discriminant analysis (SDA) to determine the variables that best predicted the occurrence of the 11 most common bird species. Those variables chosen by SDA were explained in terms of individual species' habitat preference, and foraging and nesting behavior. Forest-dwelling neotropical migrants appeared in habitats where values of mean canopy height, percent canopy cover, and number of large trees were greater than the average value of all four habitats. Scrub-dwelling migrants appeared in habitats where vertical vegetation profile, describing the density of live stems and

branches from 0-1 m, was greater than average. Based on this study, it would appear that mowing does not increase neotropical migrant species richness and may even be detrimental due to the attraction to hayfields by Brown-headed Cowbirds (*Molothrus ater*). Conversely, burning of fields and forests increases diversity and abundance of several species of breeding neotropical birds relative to mowing.

INTRODUCTION

Currently ornithologists are concerned over population declines of neotropical migratory songbirds in North America. Studies indicate habitat fragmentation and loss are responsible for declines of both forest-dwelling and grassland-dwelling migrants (Terborgh 1992, Chadwick 1995).

Habitat fragmentation leads to increased amounts of edge per forest area (Laurance and Yensen 1991) that may attract the Brown-headed Cowbird (*Molothrus ater*), an obligate brood parasite (Brittingham and Temple 1983). Likewise, smaller fragments may have more nest predators because larger predators are absent (Wilcove 1985). Nest parasitism and predation are two main causes for low reproductive success in both forest- and grassland-breeding birds (Robinson and Wilcove 1994, Johnson and Temple 1990).

For forest-dwelling neotropical migrants, loss of habitat may be caused by deforestation, either on breeding or tropical wintering grounds (Hagan and Johnston 1992), whereas loss of grassland habitat is due primarily to conversion to agriculture (Johnson and Schwartz 1993, Evrard and Bacon 1995, Rodenhouse et al. 1995). Wilcove and Terborgh (1984) described bird response to habitat loss as following any one of five patterns, involving combinations of contraction of a species' range and/or reduced densities in marginal and optimal habitats. Some grassland species respond to habitat loss by adapting to converted agricultural lands, for example, breeding in pastures (Paine, et al. 1995), hayfields (Pasitschniak-Arts and Messier 1995), cornfields (Best, et al. 1990), grain and legume fields (Mankin and Warner 1992) and highway right-of-ways (Paruk 1990). Conversely, forest-interior songbirds respond to habitat loss by making breeding attempts in marginal forest habitats, such as forest edges, where nest predation and parasitism are high. Those areas are referred to as population sinks (Pulliam 1988). Extensive forests such as the Ozarks and Appalachians, where birds are believed to breed successfully, appear to be population sources (Wiens and Rotenberry 1981, Terborgh 1992, Robinson et al. 1995). Land managers responsible for areas encompassing both habitats need to be aware of the potentially negative consequences to forest- and grassland-dwelling songbirds of habitat alterations.

The Buffalo National River, managed by the National Park Service, stretches 216 km across the Arkansas Ozarks, and is an area where the effect of maintaining fields in a predominantly-forested habitat is unknown. Since its inception as a national park in 1972, agricultural lands have been leased to farmers. In 1994, wildlife managers for the Buffalo National River became concerned that maintenance of old fields and hayfields were not favorable practices for conserving stable populations of neotropical migratory songbirds.

The objectives of this study were to 1) examine effects that hay and fire management have on neotropical bird species diversity and abundance to aid park managers in making management decisions, and 2) determine habitat characteristics that best predict the occurrence of individual bird species, so that managers will know which habitat characteristics are important to maintain.

STUDY AREA AND METHODS

Eleven sites were located around the Erbie Historic Area of the Buffalo National River, 16 km northwest of Jasper, in northern Newton County, Arkansas. Three hayfields, six old fields, one tract of burned deciduous forest, and one tract of secondary-growth deciduous forest were chosen for study. Common tree species of the forested sites were mockernut hickory (*Carya tomentosa*), shagbark hickory (*C. ovata*), white oak (*Quercus alba*), blackjack oak (*Q. marilandica*), sugar maple (*Acer saccharum*) and slippery elm (*Ulmus rubra*). The secondary forest site had a north-facing slope, while the burned forest site had an east-facing slope. Elevations ranged from 270-370 m. Old fields were dominated by broom sedge (*Andropogon sp.*) and widely-dispersed Eastern red cedar (*Juniperus virginiana*), sweetgum (*Liquidambar styraciflua*), persimmon (*Diospyros virginiana*), and honey locust (*Gleditsia triacanthos*). Old fields were burned in fall of 1993 and spring of 1993 and 1994. Hayfields were planted in fescue (*Festuca sp.*) and were leased annually to a local farmer who mowed them several times during summer.

Birds were censused at 30 fixed-radius point-counts following the methods of Hutto et al. (1986) in which all birds seen or heard within a 50 m radius were recorded in a ten-minute interval. Birds greater than 50 m away or flying over plots were recorded, but not included in analyses. Six point-counts each were located in the tracts of secondary growth and burned forests. Two point-counts were located in each of three hayfields. Twelve point-counts were located in five old fields: three point-counts in three fields, two point-counts in one field, and one point-count in another old field. Point-counts were at least 50 m apart from one another. Each point-count was surveyed four times between 18 May and 16 June 1994, from 0600 to 1100 hours. Starting times for each point-count varied to account for daily variation in singing activity. No censuses were conducted under rainy or windy conditions. In June 1994, two people searched for nests in hayfields by pulling a weighted cable between them.

Vegetation characteristics around each point-count were sampled using modified James and Shugart (1970) techniques (see Martin and Geupel 1993). All vegetation sampling was done in July 1994. The nineteen habitat variables measured are listed in Table 1. Within a 5-m radius around the point-count center, percent of vegetation below 0.5 m in height was estimated and further broken down into either percent grass, forb, fern, moss, downed log, bare ground, or leaf litter. Depth of leaf litter was measured at six locations along each of two transects running north/south

The five most abundant bird species in secondary forest, burned forest, and old field were entered into a stepwise-discriminant analysis procedure. The top five were chosen because sample sizes were adequate to carry out the analysis. Hayfields were discarded from the analysis because the four bird species found there were in low abundance. The discriminant analysis procedure screened the entire set of habitat variables and determined the subset of habitat variables that best predicted presence of the chosen subset of bird species. For each predictor habitat variable, values over all four habitats were averaged to obtain an overall habitat mean. For each bird species, values for that same predictor habitat variable were averaged over only the habitats where the bird species occurred to obtain a species mean. If the species mean was higher than the overall habitat mean, a plus sign is indicated in Table 3. If the species mean was lower than the overall habitat mean, a negative sign is indicated.

Discriminant function analysis estimated how accurately the variables chosen by SDA are in predicting the presence of individual species. All statistical analyses were performed on a mainframe computer using Statistical Analysis Software (SAS Inst. Inc. 1989).

RESULTS

Forty bird species were identified in the four habitats (Table 2). (Latin names of bird species are given in Appendix A.) Several species were among the five most abundant in two or all habitats. Red-eyed Vireo was abundant in three habitats, while Blue-gray Gnatcatcher and Acadian Flycatcher were abundant in both secondary and burned forest.

Old fields supported the largest number of bird species (29), 16 of which were neotropical migrants. Of those 16, eight appeared only in old fields: Barn Swallow, Blue-winged Warbler, Prairie Warbler, Common Yellowthroat, Yellow-breasted Chat, American Redstart, Blue Grosbeak, and Savannah Sparrow. The most common species in old fields were Red-eyed Vireo, Prairie Warbler, Indigo Bunting, Rufous-sided Towhee, and Field Sparrow.

The burned forest supported 17 species, 12 of which were neotropical migrants. Of those 12, three appeared only in the burned forest: Yellow-throated Vireo, Scarlet Tanager, and Summer Tanager. The most common species were Acadian Flycatcher, Blue-gray Gnatcatcher, Yellow-throated Vireo, Red-eyed Vireo, and Summer Tanager.

The secondary forest contained 12 bird species, eight of which were neotropical migrants; no species appeared solely in this habitat. The most common species were Acadian Flycatcher, Blue-gray Gnatcatcher, Yellow-throated Vireo, Red-eyed Vireo, and Black-and-white Warbler.

Hayfields contained only four species, two of which were neotropical migrants: Northern Rough-winged Swallow and Indigo Bunting. Based upon point-count results, no bird species appeared only in hayfields, although Eastern Meadowlarks (*Sturnella magna*) were spotted in one hayfield before censusing began.

The subset of habitat variables chosen by stepwise discriminant analysis for predicting presence in a given habitat of the five most abundant species is given in Table 3. Selected variables that predict presence of forest-dwelling neotropical migrants are percent green vegetation (GREE), percent canopy coverage (DENS), mean canopy height (CAHT), number of trees 8-23 cm dbh (SZCL3), and mean number of live vegetation contacts 1-2 m (HI). Of the above variables, forest-dwelling neotropical migrants occur in habitats where values for variables that describe forest stature (percent canopy coverage, mean canopy height, and number of trees 8-23 cm dbh) are above average. Values for variables that describe forest understory (GREE, HI) are below the overall habitat average.

Selected variables that predict presence of scrub-inhabiting neotropical migrants are mean canopy height (CAHT), percent canopy coverage (DENS), and mean number of live vegetation contacts 0-1 m (L0). Of these, only values for LO, which describes vertical vegetation stratification near ground-level, are higher than average. The other two variables (CAHT and DENS), which describe forest structure, have values below average. For short-distance migrants, the same pattern holds true. Percent green vegetation has values above average, while canopy height and percent litter (LTR) have values below the overall habitat average. Only one resident bird species was abundant enough to be included in analyses: Tufted Titmice occupied habitats where values for number of trees 2.5-8 cm and trees 23-38 cm dbh were greater than average.

Based on 24 observations (sum total of point-counts in old field, burned forest, and secondary forest), the discrimination model assessed that variables chosen by SDA predicted the presence of indiviual bird species with an accuracy ranging from 71% to 100% (Table 3).

DISCUSSION

The low number of birds utilizing hayfields indicates that maintaining fescue hayfields along the Buffalo River is not an effective land use for attracting grassland-dwelling neotropical migrants. Hayfields may actually be detrimental because edges created between hayfield and forest may attract Brown-headed Cowbirds. Additional point-counts conducted on edges of hayfields revealed up to six cowbirds within one point-count around one field, and two cowbirds around another. Of the four neotropical bird species present, two migrant species are not suffering population declines in North America, and can be found in other habitats along the Buffalo River. Use of the hayfields by those species appeared limited to foraging, since no nests were found in 1994. Occasionally, Northern Rough-winged Swallows were observed flying over the fields, presumably catching insects. The sole observation of Northern Cardinal was of a male foraging in freshly-cut hay. Two Field Sparrows were observed on one day, using hay bales as perches. Indigo Buntings would occasionally be observed foraging in the grass.

Fescue fields are capable of supporting a number of grassland birds. The most common birds in the fescue grasslands of Canada are Horned Lark (*Eremophila alpestris*), Sprague's Pipit (*Anthus spragueii*), Baird's Sparrow (*Ammodramus bairdii*), Vesper Sparrow (*Pooecetes gramineus*), Savannah Sparrow, Clay-colored Sparrow (*Spizella pallida*), Chestnut-collared Longspur(*Calcarius ornatus*), and Western Meadowlark (*Sturnella neglecta*)(Owens 1971, Pylypec 1991), none of which nest in Arkansas. However, incomplete disturbances such as mowing and grazing reduces or eliminates all species except Horned Lark and Chestnut-collared Longspur (Owens 1971, Owens and Myres 1973).

Eastern Meadowlarks were spotted in one large hayfield along the Buffalo River early in the spring of 1994 and 1995, but were not seen as the summers progressed. One nest was found in cut grass in 1995 (K. Smith, pers. obs.). Several reasons may explain the lack of grassland birds. Time of first mowing may be so early that any potentially-nesting birds are driven away, supported by the observation of Eastern Meadowlarks and the nest in the spring. One hayfield designated as a study site had to be abandoned in May because it was mowed before any censusing had begun. Secondly, only 11% of Newton County is in agricultural lands, which includes crops and pasture (Dzur et al. 1995). Therefore, grassland birds may not be attracted to the few, relatively small and widely-spaced hayfields in Newton County, but instead settle in Oklahoma or prairie remnants in southwestern Missouri (Burger et al. 1994) where there are larger bird populations and the likelihood of finding mates may be greater.

Maintenance of old fields benefits several neotropical species of concern and continuation of this management practice is encouraged. Species benefitted include Eastern Wood-Pewee, Blue-gray Gnatcatcher, Red-eyed Vireo, Blue-winged Warbler, Black-and-white Warbler, and American Redstart (Ehrlich et al. 1988). Likewise, in a study of geographic trends in warbler populations in the southeastern and southcentral United States, James et al. (1989) report that Common Yellowthroat and Prairie Warbler are in decline in the uplands, which includes the Ozark/Ouachita plateau. Carey et al. (1994) report a decline in Field Sparrow populations due to clearing of shrubby fields for agriculture or suburban development.

At first glance, burned forests appear to be the only site that supports Yellow-throated Vireo, and Scarlet and Summer tanagers. However, several bird species found in the burned forest site or in old fields would also be expected to occur also in secondary forests. These species are the Red-bellied Woodpecker, Downy Woodpecker, Pileated Woodpecker, White-breasted Nuthatch, Yellow-throated Vireo, Scarlet Tanager, and Summer Tanager. This result could be due to sampling technique. Several of those birds were seen or heard in secondary forest, but not within the point-count circle. Also, had more than one secondary forest site been censused, some of those birds may have been observed. They have been recorded in oak/hickory forests in the nearby Ozark-St. Francis National Forest (Rodewald 1995).

Nevertheless, it would appear that burned forest is especially attractive to Acadian Flycatchers, Blue-gray Gnatcatchers, vireos, and tanagers. Smith (1977) found that Acadian Flycatchers preferred a closed canopy with an open understory, a situation describing that of the burned forest site. Bock and Bock (1983) surmise that increased postfire bird abundances may result in an increased food supply due to burning. Skinner (1989) found that aerial foragers and salliers were more abundant in postfire than in unburned ecotones. Therefore, the species found in the burned forest along the Buffalo River may be responding to an increase in insect abundance.

Results of the stepwise discriminant analysis may elucidate which habitat variables are important to individual species. Acadian Flycatchers and Blue-gray Gnatcatchers occurred in habitats with low percent green vegetation on the ground. This can be explained in terms of foraging and nesting requirements, since neither species is heavily reliant on grasses or forbs: both species forage by catching insects in the air, and Blue-gray Gnatcatchers also glean insects near tips of tree or shrub branches (Ellison 1992). Both species build nests on horizontal tree limbs (Ehrlich et al. 1988). Acadian Flycatchers were also associated with number of trees 8-23 cm dbh--indicative of a mature forest. This finding agrees with James (1971) and Smith (1977).

Yellow-throated and Red-eyed vireos, and Summer Tanagers occurred in habitats with a tall canopy. Since these birds are found in edges or open spaces with trees (Whitcomb et al. 1981, Ehrlich et al. 1988), they may cue in on suitable singing or foraging perches, rather than a dense stand of forest. Furthermore, the two vireo species were found in habitats where the herbaceous layer is not particularly well-developed, as shown by the below average values for number of live vegetation contacts 1-2 m and litter depth. This corresponds to James' (1971) result that Yellow-throated and Red-eyed vireos are found in mature forests where ground cover is low. However, it should be noted that Red-eyed Vireos were present in old fields, but not at the abundances within the forest habitats. Red-eyed Vireos are the most abundant species within the forests, and individual birds occupying territories in the forest edge may be forced to utilize old fields for supplemental foraging.

Summer Tanagers displayed a below average value for canopy coverage, which agrees with the findings of Shy (1984). In comparing habitat structure between Scarlet and Summer tanagers over large areas of their breeding ranges, Shy observed that Summer Tanagers establish territories in more open vegetation with smaller values of percent canopy cover, canopy height, and density of large trees than Scarlet Tanagers in the same range.

Black-and-white Warblers were found in habitats with above average values for canopy coverage. They are a woodland species that forage on tree trunks in second-growth forests (Kricher 1995). Conner et al. (1983) reported an association between Black-and-white Warblers and increasing percent canopy closure, while Clark et al. (1983) associated the species with high canopy volume.

Two neotropical migrants of old fields, Prairie Warblers and Indigo Buntings, showed above average values for number of live vegetation contacts from 0-1 m, and below average values for canopy height and canopy coverage. Since old fields consisted mainly of grasses and widely-spaced trees, the latter of which were rarely inside vegetation plots, these findings are as expected. The variables chosen by stepwise discriminant analysis concur closely with variables comprising the major principal component in James' (1971) study analyzing characteristic habitat dimensions of individual species. The first principal component was most highly correlated with number of species of trees, percent canopy cover, number of small trees, and canopy height, and Prairie Warblers were placed at the far end of the spectrum representing open-country birds located in habitat with high ground cover and few trees.

Rufous-sided Towhees and Field Sparrows are short-distance migrants of edge and scrubby habitat. Therefore, it is not surprising that they showed below average values for canopy height in the study sites. However, based on the Rufous-sided Towhee's foraging method of scratching for food in litter, one would expect this species to occur in habitats where leaf litter is abundant. One explanation for this is that the site where towhees were most abundant was a recently-burned old field, so that leaf litter would not have had as much time to accumulate. Field Sparrows also occurred in habitats with high percent green vegetation. Field Sparrows are highly dependent on grasses for nest-building, nest concealment, and foraging (Carey et al. 1994).

The sole resident species evaluated, Tufted Titmice, exhibit above average values for number of trees 2.5-8 cm and 23-38 cm dbh. Conner et al. (1983) found Tufted Titmice to be associated with increasing percent of sapling hardwoods and large tree density, while Smith (1977) found Tufted Titmice to be associated with xeric forest. In the present study, this species occurred in both secondary and burned forest, and the greatest density of trees in both habitats fell within the 2.5-8 cm size class, so that this habitat variable may simply reflect the species' preference for forests. Since the Tufted Titmouse nests in cavities, it may be attracted to large, older trees that contain cavities, which would be found in trees 23-38 cm dbh.

Stepwise discriminant analysis is a useful technique for determining the most important variables associated with a particular species. Results of this study agreed with those of investigators using other techniques, such as prinicpal component analysis (James 1971, Smith 1977), which reduces a large set of variables into two or three uncorrelated combinations or principal components (Manly 1986). The present study indicates that fire management of mature forest with well-developed canopy is beneficial to aerial flycatchers more so than unburned forest, whereas fire management of fields to sustain grasses and scattered trees is beneficial to scrub- and edge-inhabiting neotropical migrants. Hay management was not beneficial to neotropical migrants and discontinuation of this practice in favor of old field succession is suggested for consideration.

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Table 1. Mean and standard error (SE) of 19 vegetation characteristics measured on point-counts along the Buffalo National River, AR.

	Secondary Forest Mean(SE)	Burned Forest Mean(SE)	Old field Mean(SE)	Hayfield Mean(SE)
Measured Within 5 m Radius				
1. No. Saplings 0-2.5 cm(SZCL1)	16.3(3.3)	2.3(1.5)	6.5(4.5)	-------
2. No. Saplings 2.5-8 cm(SZCL2)	6.5(1.6)	3.0(0.7)	0.8(0.3)	-------
3. Percent Green Vegetation below 0.5 m(GREE)	41.5(4.4)	21.3(3.5)	80.1(4.9)	85.8(5.2)
4.*Percent Grass Cover below 0.5 m(GRAS)	9.2(2.5)	2.1(1.6)	51.7(7.1)	72.1(8.3)
5.*Percent Moss below 0.5 m(MOSS)	13.8(4.0)	-------	-------	-------
6.*Percent Forb below 0.5 m(FORB)	16.9(3.0)	19.2(3.6)	26.5(5.6)	13.6(3.7)
7.*Percent Fern below 0.5 m(FERN)	1.1(0.7)	-------	-------	-------
8.*Percent Logs(LOGS)	1.1(1.1)	2.4(0.2)	-------	-------
9.*Percent Bare Ground(GRD)	1.5(1.0)	58.8(6.6)	13.6(4.9)	1.3(1.3)
10. Percent Leaf Litter(LTR)	49.2(7.7)	20.6(4.5)	25.9(10.1)	27.5(8.3)
11. Percent Canopy Coverage below 5 m(CACV)	88.7(2.2)	84.1(2.6)	12.3(7.4)	-------
12. Percent Canopy Coverage above 5 m(DENS)	84.9(2.8)	14.6(14.6)	-------	-------
13. Mean Litter Depth in mm(LTDEP)	29.5(4.1)	13.1(3.5)	14.3(0.9)	26.6(5.5)
14. Mean Canopy Height in m(CAHT)	15.0(0.7)	19.0(0.9)	2.5(6.1)	0.4(0.0)
Measured Within 11.3 m Radius				
15. No. Trees 8-23 cm dbh(SZCL3)	12.5(2.3)	11.2(1.9)	1.5(0.6)	-------
16. No. Trees 23-38 cm dbh(SZCL4)	5.0(1.1)	3.7(0.7)	0.3(0.2)	-------
17. No. Trees >38 cm dhb(SZCL5)	1.0(0.4)	1.2(0.8)	-------	-------
18. Live Vegetation Profile Mean Contacts 0-1 m(LO)	0.3(0.1)	0.4(0.1)	4.5(0.4)	3.0(0.3)
19. Live Vegetation Profile Mean Contacts 1-2 m(HI)	0.6(0.1)	-------	0.0(0.0)	-------

*Not included in statistical analyses

Table 2. Mean abundance and standard error per point count for breeding bird species recorded along Buffalo National River, Arkansas, 1994. The five most abundant species in the first three habitats are in bold print. Dashes indicate absence of species from the habitat. Mean or SE values of 0.0 indicate birds were present in the habitat, but at very low abundances.

	Secondary Forest Mean(SE) n=6	Burn Forest Mean(SE) n=6	Old field Mean(SE) n=12	Hayfield Mean(SE) n=6
Northern Bobwhite	----	----	0.1(0.0)	----
Mourning Dove	----	----	0.0(0.0)	----
Yellow-billed Cuckoo	0.0(0.0)	0.0(0.0)	----	----
Ruby-throated Hummingbird	----	0.0(0.0)	0.1(0.1)	----
Red-bellied Woodpecker	----	0.0(0.0)	0.0(0.0)	----
Downy Woodpecker	----	0.1(0.1)	----	----
Pileated Woodpecker	----	----	0.0(0.0)	----
Eastern Wood-pewee	----	0.2(0.1)	0.1(0.1)	----
Eastern Phoebe	----	----	0.1(0.1)	----
Acadian Flycatcher	**0.2(0.1)**	**0.6(0.2)**	----	----
Northern Rough-winged Swallow	----	----	0.1(0.0)	0.5(0.3)
Barn Swallow	----	----	0.1(0.1)	----
Blue Jay	0.0(0.0)	0.0(0.0)	0.0(0.0)	----
Tufted Titmouse	**0.1(0.1)**	0.1(0.1)	----	----
Carolina Chickadee	0.1(0.1)	----	0.1(0.0)	----
White-Breasted Nuthatch	----	0.0(0.0)	----	----
Carolina Wren	0.0(0.0)	----	----	----
Blue-gray Gnatcatcher	**0.8(0.1)**	**1.1(0.2)**	0.2(0.1)	----
White-eyed Vireo	0.0(0.0)	----	0.1(0.1)	----
Yellow-throated Vireo	----	**0.3(0.1)**	----	----
Red-eyed Vireo	**1.8(0.2)**	**1.6(0.1)**	**0.2(0.1)**	----

Table 2. Continued.

	Secondary Forest Mean(SE) n=6	Burn Forest Mean(SE) n=6	Old field Mean(SE) n=12	Hayfield Mean(SE) n=6
Blue-winged Warbler	----	----	0.0(0.0)	----
Northern Parula	0.0(0.0)	0.1(0.1)	----	----
Black-and-white Warbler	**0.3(0.1)**	0.0(0.0)	0.0(0.0)	----
Prairie Warbler	----	----	**0.7(0.2)**	----
Ovenbird	0.0(0.0)	0.1(0.1)	----	----
Common Yellowthroat	----	----	0.1(0.1)	----
Yellow-breasted Chat	----	----	0.1(0.0)	----
American Redstart	----	----	0.0(0.0)	----
Northern Cardinal	----	----	0.1(0.1)	0.0(0.0)
Blue Grosbeak	----	----	0.1(0.1)	----
Indigo Bunting	----	----	**1.2(0.1)**	0.2(0.2)
Rufous-sided Towhee	----	----	**0.2(0.1)**	----
Savannah Sparrow	----	----	0.1(0.1)	----
Field Sparrow	----	----	**0.3(0.2)**	0.1(0.1)
Chipping Sparrow	----	----	0.1(0.1)	----
Brown-headed Cowbird	----	----	0.0(0.0)	----
Scarlet Tanager	----	0.0(0.0)	----	----
Summer Tanager	----	**0.1(0.1)**	----	----
American Goldfinch	----	----	0.1(0.0)	----

Table 3. Habitat variables chosen by stepwise discriminant analysis for predicting the presence of the following species. Positive and negative signs indicate whether habitat means for those habitats in which a species occurred were above or below the habitat mean over all 4 habitats. P-value based on significance level to enter model of 0.30 and significance level to stay in model of 0.10. Percent observations correctly classified determined by discriminant function analysis. Abbreviations as in Table 1.

Species	Habitat Variables		P	% Correct Classifications
Neotropical Migrants-Forest Interior:				
Acadian Flycatcher	GREE	-	.0001	88
	SZCL3	+	.060	
Blue-gray Gnatcatcher	GREE	-	.0010	83
Yellow-throated Vireo	CAHT	+	.0008	96
	HI	-	.0002	
Red-eyed Vireo	CAHT	+	.0006	88
	LTDEP	-	.0031	
Black-and-white Warbler	DENS	+	.0001	88
Summer Tanager	CAHT	+	.0508	88
	DENS	-	.0229	
Neotropical migrants--scrub and edge:				
Prairie Warbler	LO	+	.0001	92
Indigo Bunting	CAHT	-	.0001	100
	DENS	-	.0003	
	LO	+	.0135	
Short-distance migrants:				
Rufous-sided Towhee	CAHT	-	.0165	71
	LTR	-	.0655	
Field Sparrow	CAHT	-	.0136	92
	GREE	+	.0012	
Resident:				
Tufted Titmouse	SZCL4	+	.0314	92
	SZCL2	+	.0422	

Appendix A. Common and Latin names of bird species.

Northern Bobwhite	*Colinus virginianus*
Yellow-billed Cuckoo	*Coccyzus americana*
Ruby-throated Hummingbird	*Archilochus colubris*
Red-bellied Woodpecker	*Melanerpes carolinus*
Downy Woodpecker	*Picoides pubescens*
Pileated Woodpecker	*Dryocopus pileatus*
Eastern Wood-pewee	*Contopus virens*
Eastern Phoebe	*Sayornis phoebe*
Acadian Flycatcher	*Empidonax virescens*
Northern Rough-winged Swallow	*Steigidopteryx serripennis*
Barn Swallow	*Hirundo rustica*
Blue Jay	*Cyanocitta cristata*
Tufted Titmouse	*Parus bicolor*
Carolina Chickadee	*Parus carolinensis*
White-breasted Nuthatch	*Sitta carolinensis*
Carolina Wren	*Thryothorus ludovicianus*
Blue-gray Gnatcatcher	*Polioptila caerulea*
White-eyed Vireo	*Vireo griseus*
Yellow-throated Vireo	*Vireo flavifrons*
Red-eyed Vireo	*Vireo olivaceus*
Blue-winged Warbler	*Vermivora pinus*
Northern Parula	*Parula americana*
Black-and-white Warbler	*Mniotilta varia*
Prairie Warbler	*Dendroica discolor*
Ovenbird	*Seiurus aurocapillus*
Common Yellowthroat	*Geothlypis trichas*
Yellow-breasted Chat	*Icteria virens*
American Redstart	*Setophaga ruticilla*
Northern Cardinal	*Cardinalis cardinalis*
Blue Grosbeak	*Guiraca caerulea*
Indigo Bunting	*Passerina cyanea*
Rufous-sided Towhee	*Pipilo erythrophthalmus*
Savannah Sparrow	*Passerculus sandwichensis*
Field Sparrow	*Spizella pusilla*
Chipping Sparrow	*Spizella passerina*
Brown-headed Cowbird	*Molothrus ater*
Scarlet Tanager	*Piranga olivacea*
Summer Tanager	*Piranga rubra*
American Goldfinch	*Carduelis tristis*

CHAPTER 2

EFFECTS OF RIPARIAN FOREST STRIPS ON ARTIFICAL NEST SUCCESS

This chapter is written in the format of a manuscript for the *Journal of Wildlife Management*.

Abstract: Riparian forest strips provide important and unique habitat for bird species, exhibiting both wetland and upland characteristics that increase plant diversity. While bird species richness and diversity within riparian strips may be high, low nesting success within riparian forest strips may counterbalance the increase in species abundance. This study examined the relationship between proportion of depredated nests within riparian forest strips and landscape and habitat characteristics, as well as examined differences in nest-site and nest-patch characteristics between successful and unsuccessful nests. From June to July 1995, 110 artificial nests were placed in 8 strips located along the Buffalo National River, Arkansas, USA. Bird species utilizing forest strips were recorded as an indicator of species that utilize riparian strips. Proportions of depredated nests among the 8 sites varied from 0.17 to 1.00; 4 of the sites experienced 100% depredation. Habitat variables that explained differences in proportion of depredated nests were vertical vegetation hits 0-1 m ($\underline{P}$ = 0.0168) and slope ($\underline{P}$ = 0.0266). As vertical vegetation hits increased and slope decreased, proportion of depredated nests increased. Nest-patch variables that explained differences between successful and unsuccessful nests were number of trees 8-23 cm dbh ($\underline{P}$ = 0.0169) and vertical

vegetation hits 0-1 m (P = 0.0252). Vertical vegetation hits measured density of understory; proportion of depredated nests increased 60% as understory increased and tree density was low around the nest, but influence of understory on depredation decreased as tree density increased. These results are consistent with the suggestion that both canopy and ground predators were present: when tree density is high, canopy predators take advantage of trees to scan for prey, including possible ground predators such as snakes and small mammals. When understory is high, ground predators have cover to protect movements. Twenty-four bird species were recorded within riparian forest strips, 6 of which were not recorded in adjacent fields and upland forest. Although riparian forest strips attract bird species, some of which are common only in riparian areas, the high proportion of depredated nests suggests low nesting success. Vegetation characteristics around individual nests and within strips may be more important to nesting success than strip width or adjacent land uses.

INTRODUCTION

Nest depredation is the main cause of nesting mortality for many bird species (Ricklefs 1969, Martin 1992); therefore, nest-site selection may be an important determinant of a bird's reproductive success (Martin 1988). Habitat characteristics in the vicinity of a nest may influence nest detection by a predator and, thus, probability of depredation. Martin and Roper (1988) identified two levels at which nest selection may occur: nest-site (the area immediately surrounding the nest), and nest-patch (characteristics of the habitat patch in the immediate surroundings of a nest). Examples of nest-site characteristics are degree of nest concealment, nest height, nest substrate, and nest orientation relative to main stem (Yahner and Cypher 1987, Martin and Roper 1988, Yahner and Voytko 1989, Götmark et al. 1995, Tarvin and Smith 1995). Examples of nest-patch characteristics include vertical vegetation density, percent ground cover (Leimgruber et al. 1994), homogeneity of vegetational coverage (Joern and Jackson 1983), number and size class of woody stems (Martin and Roper 1988, Tarvin and Smith 1995), and percent canopy cover (Tarvin & Smith 1995). Studies at the nest-site and nest-patch level have found that predation rate decreases with availability of other potential nest sites (Martin and Roper 1988), high to intermediate levels of nest concealment (Götmark et al. 1995), and high herbaceous ground cover and foliage density (Leimgruber et al. 1994).

A third level, that of the general habitat type within which a nest is located, may affect depredation due to such considerations as differences in vegetative structure and stand area (Yahner and Wright 1985, DeGraaf and Angelstam 1993). Vegetative structure may reduce predator foraging efficiency (Bowman and Harris 1980), whereas stand area may be related to amount of edge and, therefore, number of predators attracted to edge.

A fourth level influencing nest depredation is that of the landscape, defined by Freemark et al. (1995) as the composition, abundance, and placement of habitat patches. The surrounding land uses within which a particular habitat is located can influence abundance and composition of generalist and specialist predators. Andrén (1992) examined how abundance and distribution of four corvid species, all nest predators, shifted in relation to amount of agricultural land located adjacent to forest. He found that different habitats attract different predators; thus, the landscape surrounding a particular habitat could influence the species and abundance of predators within the habitat.

This study examined relationships between nest depredation and nest-site, nest-patch, habitat and landscape variables in riparian forest strips surrounded by agricultural fields. Riparian forest strips are vital to ecosystem health because of their buffer effect on aquatic habitats (Darveau et al. 1995, Barton et al. 1985), and high mammal and bird species richness (Doyle 1990, Stauffer and Best 1980) compared to upland habitat. However, because of the edge habitat inherent in forest strips, they may attract nest parasites and predators, and, thus, be ecological traps (Gates and Giffen 1991). Few studies have examined the relationship between nest depredation and nest-site, nest-patch, habitat, and landscape characteristics in riparian forest strips. Although bird species richness may be high in riparian areas, it is unclear whether breeding birds raise successful clutches. Through artificial nests, this study attempted to assess relative predation rates within forested riparian areas. Objectives of this study were to determine 1) whether proportion of depredated artificial nests would differ among 8 riparian strips, 2) which measured habitat and landscape variables could account for these differences, 3) where differences existed in nest-site and nest-patch variables between successful and unsuccessful nests from the 8 sites, and 4) which bird species were utilizing riparian forest strips.

STUDY AREA AND METHODS

Eight non-continuous forested strips were located along the upper Buffalo River from Boxley to Pruitt in Newton County, AR. Each site was bordered on one side by the Buffalo River and on the opposite side by either a hayfield or an old field. Width of the sites was variable, while length of each study site was fixed at 40 m. Common tree species of the sites were elm (Ulmus sp.), sweetgum (Liquidambar styraciflua), Eastern red cedar (Juniperus virginiana), box elder (Acer negundo), sycamore (Platanus occidentalis), red and white oak (Quercus sp.), hickory (Carya sp.), and witch hazel (Hamamelis virginiana).

Possible nest predators included snakes, primarily black rat snakes (Elaphe obsoleta), American crow (Corvus brachyrhynchos), raccoon (Procyon lotor), striped skunk (Mephitis mephitis), coyote (Canis latrans), gray fox (Urocyon cinereoargenteus), red fox (Vulpes fulva), bobcat (Lynx rufus), gray squirrel (Sciurus carolinensis), fox squirrel (S. niger), and Virginia opposum (Didelphis virginiana). An attempt was made to identify nest predators using track boards (Angelstam 1986), but no tracks were left on the boards. Thus, most of the predation was presumed to have been caused by birds, squirrels, or snakes invading the nests from the canopy. Black rat snakes have been documented as effective nocturnal predators of birds in the Ozarks (Hensley and Smith 1986), and at one site a black rat snake was located mid-canopy in river cane (Arundinaria gigantea). Squirrels and crows were frequently observed within the study area.

Wicker cup nests were purchased locally from a pet store and spray-painted in camouflage colors to reduce visibility. Northern bobwhite (Colinus virginianus) eggs were purchased from a local breeder. Artificial nests were located above ground within each site in an area-dependent manner of one nest per 200 m^2. A transect marked with flags at 10 m intervals was located through the center of each site. A grid overlayed on diagrams of each site and a table of random numbers were used to determine how many meters down and to right or left of transect the nests should be placed. Compass bearings were taken from nests to the nearest flag on the transect and a brief description of nest location was recorded for ease in finding nests for nest-checks. Nests were checked for signs of egg depredation every three days for two weeks, from 5 June to 17 June 1995. Number of eggs remaining was recorded at each check.

Landscape, habitat, and nest variables were measured between 30 June and 19 July 1995. At the landscape level, the kind of field, either hayfield or old field, was noted.

Measurements of field size were obtained from the National Park Service. Quantified habitat characteristics within each site were site width, density and size class of sapling and tree species, shrub density and cover, vertical vegetation profile, canopy height, slope, and height of site above river. Site width was determined by a tape measure. The belt transect method of Barbour et al. (1987) was used to quantify shrub and tree variables. Two transect lines, located equidistant from the center of the site, were placed across the width of each site from the river's edge to the field. Both transect lines were divided into 10 m segments. Within each 10 m segment and 5 m on either side of the transect line, saplings and trees were recorded by species into size classes as measured by diameter at breast height (dbh): 2.5-8 cm, 8-23 cm, and >38 cm. Shrub density was determined by recording number of shrubs for each species within each segment that contacted the transect line. Data were expressed as number of contacts/10 m. Shrub percent cover was determined by recording the contact distance on the transect line for each species. Within each transect segment, vertical vegetation profiles, or number of contacts of live vegetation on a pole placed haphazardly within each segment, were recorded between 0-1 m and 1-2 m. Average canopy height and slope were obtained using a clinometer.

To determine height above river, the distance between the river's edge and a point located several meters within the site was multiplied by the sine of the angle between them.

Nest-patch variables were measured within a 5 m and 11.3 m radius around the center of the nest (James and Shugart 1970, see also Martin and Geupel 1993). Variables measured within 5 m were litter depth, vertical vegetation profile, percent of ground covered in green vegetation or in litter, and number and size class of saplings. Litter depth was measured along 2 transects running north/south and east/west from the center of the nest. A trowel with a mm scale was used to measure depth of litter down to mineral soil in 12 locations along the 5 m radius transect. Vegetation profiles were recorded at five haphazard locations along each transect line. Percentages of ground cover below 0.5 m in height were measured within the 5 m circle as either green vegetation or leaf litter. Saplings were recorded by species into size classes 0-2.5 cm and 2.5-8 cm as measured 10 cm above ground. Within an 11 m radius around the nest, trees were recorded by species into dbh size classes: 8-23 cm, 23-38 cm, and >38 cm.

Nest-site variables were nest height, canopy closure above the nest, percent overhead cover 1 m above the nest, percent side cover 1 m on four sides of the nest in the cardinal directions, and distance from nest to site edge. Nest height was measured with a meter stick. A spherical densiometer was used to measure canopy cover. Percent cover classes of 0-5%, 6-25%, 26-50%, 51-75%, and 76-100% (Daubenmire 1968) were used to estimate vegetation coverage up to 1 m above the nest. These same cover classes were used to estimate side coverage on 4 sides of the nest; average side cover was then calculated. Distance from nest to site edge was not measured in the field, but calculated from knowledge of nest location relative to the transect line through the center of the site. To determine bird species composition, 1 fixed-radius point-count (Hutto et al. 1986) was placed within the center of each site and visited 4 times between 8 June and 11 July 1995 (Appendix A).

Data Analysis

Number of eggs remaining at each site was converted to proportion of depredated nests. A depredated nest was defined as a nest with 1 or both eggs missing, or present but crushed. Depredation of individual nests were assumed to be independent events. An initial test for equality of depredation proportions among sites was tested using Fisher's exact test (Sokal and Rohlf 1981).

Proportion of depredated nests was transformed with arcsine square root transformation. Transformed proportions were analyzed using a two-sample t-test for the landscape variable field type. Linear regression was used to analyze whether a relationship existed between transformed proportions of depredated nests and the landscape and habitat variables field size, site width, density of saplings and trees within each size class, shrub density, shrub cover, vertical vegetation profile, canopy height, slope, and height above river.

Nest-patch and nest-site variables at successful nests were compared to values at unsuccessful nests. A two-sample t-test or Wilcoxon rank sum test was used on the continuous variables, depending on results of a preliminary check for normality. Continuous variables were nest height, distance of nest to edge, canopy closure, litter depth, vertical vegetation hits 0-1 m and 1-2 m, and number of saplings and trees in respective size classes. For the categorical variables overhead and side cover, percent green vegetation, and percent litter, Fisher's exact test was used.

Logistic regression (Hosmer and Lemeshow 1989) was used to model the probability of successful nests as a function of the nest-site and nest-patch variables. A preliminary stepwise logistic regression was run using those variables which were significantly different for successful and unsuccessful nests to identify potential independent variables. Significance level was 0.30 to enter the stepwise logistic regression model and 0.15 to stay. Preliminary results were used as the basis of a final model fitting. The final fitted model was subjected to Hosmer and Lemshow's (1989) goodness-of-fit test for model adequacy. All data analyses were performed on mainframe computer using Statistical Analysis Software (SAS Inst. Inc. 1989).

RESULTS

Fisher's exact test revealed significant differences in proportion of depredated nests among sites (P < 0.0001). For 6 of 8 sites, depredation occurred quickly, within the first 6 days after nest placement (Table 1). Within all 8 sites, 83 (75.5%) nests were unsuccessful and 27 (24.5%) were successful.

The two-sample t-test indicated depredation did not differ between field types (t=1.28, df=6, P = 0.2469). Of the landscape and habitat variables analyzed using linear regression, vertical vegetation hits 0-1 m (P = 0.0168) and slope (P = 0.0266) were significant (Table 2). From these results it appears that as slope decreases and vertical vegetation hits between 0-1 m increases, predation increases. Density of trees >38 cm dbh ($\underline{P}$ = 0.0777), field size ($\underline{P}$ = 0.1269), site width ($\underline{P}$ = 0.1741), shrub density ($\underline{P}$ = 0.3270), shrub cover ($\underline{P}$ = 0.4830) canopy height ($\underline{P}$ = 0.4082), height above river ($\underline{P}$ =0.4752), vertical vegetation hits 1-2 m ($\underline{P}$ = 0.9845), density of saplings 2-8 cm ($\underline{P}$ = 0.5611), density of trees 8-23 cm dbh ($\underline{P}$ = 0.5625), and density of trees 23-38 cm dbh ($\underline{P}$ = 0.8021) were not significant.

Results of the two-sample $\underline{t}$-test for comparing successful and unsuccessful nests indicated that no normally-distributed nest-site or nest-patch variables were significant (Table 3). Number of trees 8-23 cm dbh ($\underline{P}$ = 0.0701), vertical vegetation hits 0-1 m ($\underline{P}$ = 0.2001), and canopy closure ($\underline{P}$ = 0.2114) were included in the stepwise logistic regression. Variables that were not included were nest height ($\underline{P}$ = 0.6734) and litter depth (P = 0.4021). Number of saplings 0-2.5 cm ($\underline{P}$ = 0.0912) was the only result of the Wilcoxon rank sum test allowed in the stepwise logistic regression (Table 3).

Fisher's exact test determined that distributions of the categorical variables overhead cover ($\underline{P}$ = 0.716), side cover ($\underline{P}$ = 0.794), percent green vegetation ($\underline{P}$ = 0.676), and percent litter ($\underline{P}$ = 0.335) were not different for successful and unsuccessful nests.

Vertical vegetation hits 0-1 m, number of saplings 0-2.5 cm, number of trees 23-38 cm dbh, and canopy closure were first run in a stepwise logistic regression. Number of saplings did not meet the criteria for inclusion, and logistic regression was run on the remaining three variables. One nest was removed from analysis because it appeared to be an influential observation that did not belong to the population being tested (Byrkit 1987). This nest was located at the edge of a small clearing within the forested strip and, therefore, habitat values associated with the nest-patch were at extreme ends of the range of values from all nests. Canopy closure ($\underline{P}$ = 0.1447) was disgarded. The final logistic regression model is summarized in Table 4 and plotted in Figure 1. The model indicated that number of trees 8-23 cm dbh ($\underline{P}$ = 0.0169) and vertical vegetation hits 0-1 m ($\underline{P}$ = 0.0252) were significant. Based on the Hosmer and Lemeshow goodness-of-fit test, the fitted model was adequate ($\underline{P}$ = 0.6516).

Twenty-four bird species were censused within forest strips (Appendix A). Six of these, belted kingfisher (*Megaceryle alcyon*), northern parula (*Parula americana*), yellow-throated warbler (*Dendroica dominica*), Kentucky warbler (*Oporornis formosus*), hooded warbler (*Wilsonia* *citrina*), and American redstart (*Setophaga ruticilla*) were not detected in fields or upland forest (unpubl. data).

DISCUSSION

Differences in proportion of depredated nests between forested riparian sites could be due to a number of factors: abundance and composition of predator population, land uses surrounding the sites, vegetation characteristics within the site, vegetation characteristics surrounding individual nests, and placement and concealment of individual nests.

Unfortunately, decisive statments about predator populations cannot be made since no tracks were left on track boards, other than that predators were possibly birds, squirrels, or snakes. In this study, neither type or area of adjacent land use helped explain differences in proportion of depredated nests, nor did the area of the site itself. Most characteristics describing the floristic structure and topography within each site were nonsignificant, with the exception of vertical vegetation hits 0-1 m and slope. More large trees >38 cm dbh was suggestive of increased depredation. These results indicate presence of two general classes of predators, ground and canopy dwellers.

Number of vertical vegetation hits 0-1 m, as an indicator of density of low-growing, understory vegetation, may affect movement of ground predators and foraging efficiency. High densities of low vegetation allow a predator to travel undetected through an area, or, conversely, hamper movement. Hensley and Smith (1986) and Joern and Jackson (1983) found that snakes preferred following fencelines and other continuous vegetation to traveling in the open, but Bowman and Harris (1980) found that low vegetation decreased raccoon foraging efficiency. In the present study, an increase in low vegetation caused an increase in depredated nests, suggesting that predators preferred coverage. Also, relatively level slopes may make travel and searching easier. Higher densities of trees >38 cm dbh within sites having a high proportion of depredated nests may be explained in terms of canopy predators, such as birds, squirrels, and snakes, that use large trees as lookout posts.

In a comparison of unsuccessful to successful nests, the important variables were number of medium-sized trees (8-23 cm dbh) and number of vegetation hits 0-1 m within the 11 m nest-patch within which the nest was located. The logistic model is consistent with the idea of two general classes of predators. The first graph (Figure 1) illustrates that as understory vegetation increases in the presence of low and moderate tree density, proportion of depredated nests increases from 40% to 60%, consistent with the suggestion that ground predators use understory vegetation as cover. The influence of understory vegetation wanes as density of trees increases, which could indicate that canopy predators take over as the major predators when tree density is high, possibly preying upon ground predators.

The second graph in Figure 1 illustrates the opposite situation from the first graph: at low and moderate understory density and high tree density, proportion of depredated nests increases 60% to 70%, but the influence of tree density on depredation levels off in the presence of high understory density. This, again, would be consistent with the idea that high understory density with few trees increases ground predators. One possible explanation for this is that ground predators, such as snakes and small mammals, must be wary of their predators and are not abundant or active without a well-developed understory to hide their movements.

More conclusive results would be gained by knowledge of predator populations and individual species' modes of foraging. The use of remote-triggered cameras (Leimgruber et al. 1994) and behavioral observations (Bowman and Harris

1980) of predators is providing more information that will enhance biologists' understanding of factors influencing avian nesting success. Furthermore, caution must be taken in interpreting the importance of vegetation variables, since vegetation may be correlated with other factors (such as soil moisture and shading), which may not have been measured.

Artificial nests have a number of shortcomings and merits. They differ from natural nests in appearance, nest location, scent, egg size, and absence of birds (Leimgruber et al. 1994). However, they are a nondestructive method of examining nest depredation. They allow the researcher to control a number of confounding factors such as nest shape, height, density, position within a plant, and number of eggs (Whelan et al. 1994). Moreover, the use of artificial nests ensures adequate sample sizes, whereas locating adequate sample sizes of natural nests is very time-consuming (Yahner and Voytko 1989, Leimgruber et al. 1994).

Management Implications

Riparian forest strips are important habitat for forest birds, containing species attracted to the unique qualities of riparian forest. However, the present study illustrates that artificial nesting success can be quite low, so that high species diversity and abundance may be offset by low reproductive fitness. Although artificial nest studies provide only a relative idea of nesting success, they point out critical factors affecting success. Because vegetation variables such as density of trees and density of understory vegetation were more important indicators of nest success than distance to edge or surrounding land uses, this study highlights the importance of identifying specific habitat features that influence nesting success. Knowledge of predator behavior and foraging strategy is also a necessary component to understanding how reproductive fitness may be enhanced in bird populations.

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Table 1. Number of artificial nests depredated within 8 forested riparian strips along the Buffalo River, AR, at each nest check in June 1995. Dashes indicate no successful nests remaining within the site.

Site	# Nests Placed	Days After Placement 3	6	9	12	15	Proportion Predated Nests	Transformed Proportions[a]
1	10	10	-	-	-	-	1.00	1.41
2	4	0	0	0	1	0	0.25	0.52
3	4	2	0	0	0	0	0.50	0.79
4	28	28	-	-	-	-	1.00	1.48
5	18	15	3	-	-	-	1.00	1.45
6	18	2	1	0	0	0	0.17	0.42
7	18	1	2	0	2	5	0.61	0.90
8	10	8	2	-	-	-	1.00	1.41

[a] A proportion of 1.00 was replaced by (4n-1)/4n prior to transformation by arcsine square root.

Table 2. Results of linear regression on landscape and habitat characteristics measured within 8 riparian forest sites along the Buffalo River, AR, in July 1995.

Characteristic	$\underline{F}^{a}$	$\underline{P}$*	Slope Estimate (SE)	$\underline{R}^{2}$
Field size (ha)	3.14	0.1269	0.04(0.02)	0.3433
Site area(thousands of m^2)	2.38	0.1741	0.10(0.06)	0.2837
Shrub density (#contacts/10 m)	1.14	0.3270	0.01(0.01)	0.1595
Shrub cover (%)	0.56	0.4830	-0.01(0.01)	0.0852
Density of saplings 2-8 cm (#/m^2)	0.38	0.5611	3.13(5.08)	0.0593
Density of trees 8-23 cm dbh (#/m^2)	0.37	0.5625	8.63(14.09)	0.0589
Density of trees 23-38 cm dbh (#/m^2)	0.07	0.8021	13.19(50.33)	0.0113
Density of trees >38 cm dbh (#/m^2)	4.52	0.0777	127.68(60.08)	0.4295
Vert. veg. hits 0-1 m (#contacts)	10.78	0.0168	0.02(0.01)	0.6424
Vert. veg. hits 1-2 m (#contacts)	0.00	0.9845	-0.00(0.02)	0.0001
Slope (degrees)	8.54	0.0266	-0.11(0.04)	0.5872
Canopy height (m)	0.79	0.4082	0.03(0.03)	0.1164
Height above river (m)	0.58	0.4752	-0.07(0.09)	0.0881

* $\underline{P}$ values <0.05 indicate significance at $\alpha = 0.05$.

[a] [illegible]

Table 3. Results of t-test and Wilcoxon rank sum test for mean comparison in nest-site and nest-patch continous variables measured around artificial nests in 8 forested riparian sites along the Buffalo River, AR, in July 1995.

NORMAL VARIABLES	$\underline{t}$	df	$\underline{P}$*
Nest height (cm)	-0.42	108	0.6734
Canopy closure (%)	1.26	106	0.2114
Litter depth (mm)	-0.84	108	0.4021
Vert. veg hits 0-1 m (#contacts)	1.29	108	0.2001
Number trees 8-23 cm dbh	1.84	63.8[a]	0.0701
NON-NORMAL VARIABLES	χ^{2} [b]	**df**	$\underline{P}$*
Vert. veg hits 1-2 m (#contacts)	0.04	1	0.8428
Distance from edge (m)	0.17	1	0.6790
Number saplings 0-2.5 cm	2.85	1	0.0912
Number saplings 2.5-8 cm	0.15	1	0.6965
Number trees 23-38 cm dbh	0.01	1	0.9151
Number trees >38 cm dbh	0.28	1	0.5990

*p values < 0.10 indicate significance at $\alpha = 0.10$.

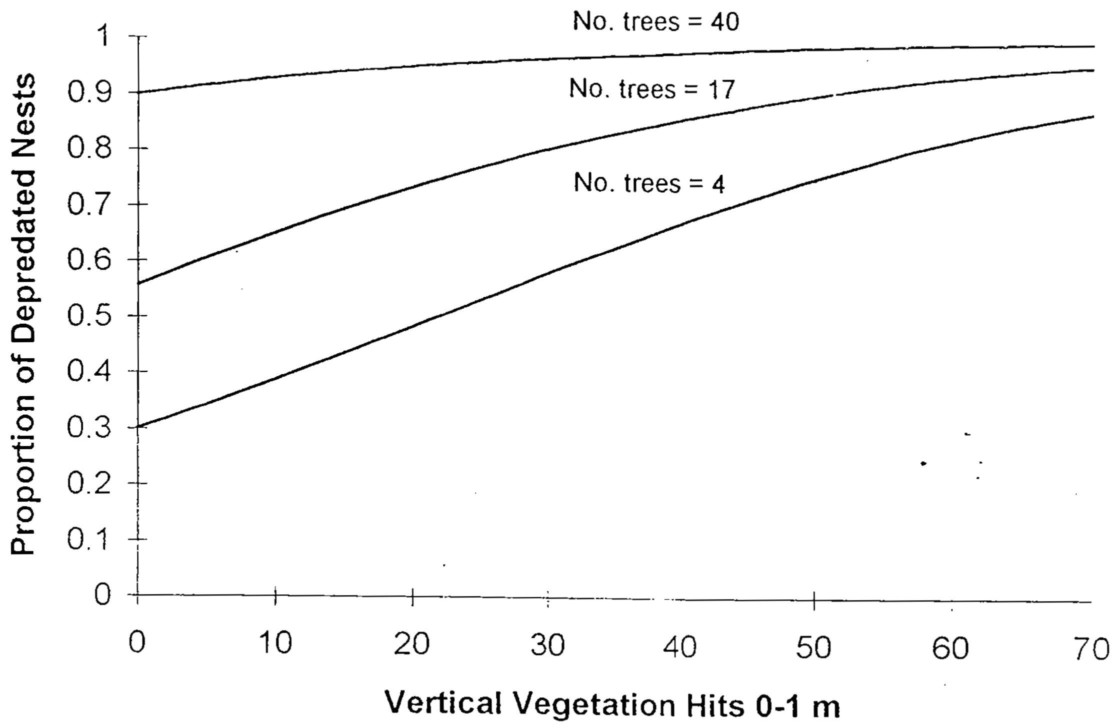
[a] For unequal variances, Sattherthwaite's approximation to the t-test was used.

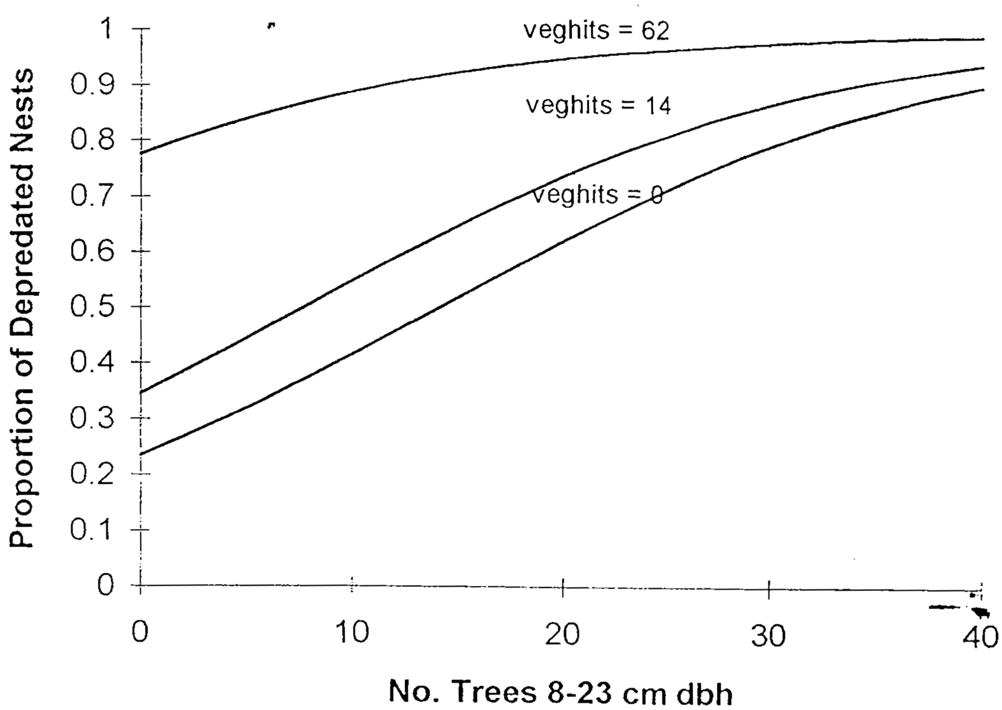
[b] χ^2 approximation to Wilcoxon statistic was used.

Figure 1. Cross-sectional representation of proportion of depredated nests as a function of number of trees 8-23 cm dbh and vertical vegetation hits 0-1 m. Logistic regression model is:

p = exp(-1.183 + .084(no. trees 8-23 cm dbh) + .039(veg hits 0-1 m)) / (1 + exp(-1.183 + .084(no. trees 8-23 cm dbh) + .039(veg hits 0-1 m)))

Values above the contours represent minimum, maximum, and mean values for vegetation hits 0-1 m and number of trees 8-23 cm dbh, respectively, as measured in the field.


No. trees = 40
No. trees = 17
No. trees = 4
Proportion of Depredated Nests
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
Vertical Vegetation Hits 0-1 m


veghits = 62
veghits = 14
veghits = 0
Proportion of Depredated Nests
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
No. Trees 8-23 cm dbh

Appendix A. List of bird species by common and Latin names that were located by fixed-radius point-count within 8 riparian forest strips along the Buffalo River, AR, from June to July, 1995.

Mourning dove	Zenaida macroura
Yellow-billed cuckoo	Coccyzus americana
Ruby-throated hummingbird	Archilochus colubris
Belted kingfisher	Megaceryle alcyon
Northern rough-winged swallow	Stelgidopteryx ruficollis
American crow	Corvus brachyrhynchos
Tufted titmouse	Parus bicolor
Carolina chickadee	Parus carolinensis
Carolina wren	Thryothorus ludovicianus
Blue-gray gnatcatcher	Polioptila caerulea
Red-eyed vireo	Vireo olivaceus
Yellow-throated vireo	Vireo flavifrons
Blue-winged warbler	Vermivora pinus
Northern parula	Parula americana
Black-and-white warbler	Mniotilta varia
Yellow-throated warbler	Dendroica dominica
Kentucky warbler	Oporornis formosus
Hooded warbler	Wilsonia citrina
American redstart	Setophaga ruticilla
Ovenbird	Seiurus aurocapillus
Yellow-breasted chat	Icteria virens
Northern cardinal	Cardinalis cardinalis
Indigo bunting	Passerina cyanea
Rufous-sided towhee	Pipilo erythrophthalmus